Published in final edited form as:
J Matern Fetal Neonatal Med. 2018 June ; 31(12): 1613–1619. doi:10.1080/14767058.2017.1322949.

Poorer Maternal Diet Quality and Increased Birth Weight

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Abstract

Objective—Maternal diet and gestational weight gain (GWG) influence birth weight and infant adiposity, which are important predictors of lifetime health. To better understand these relationships, we studied associations between maternal diet and GWG, adiposity, and birth weight in a well characterized cohort of pregnant women.

Study Design—Data were obtained from 41 term (>37 weeks), uncomplicated, singleton pregnancies according to pre-pregnancy BMI categories of normal (n=11), overweight (n=15) or obese (n=15). Daily consumption of protein, fat, and carbohydrates and a Healthy Eating Index (HEI-2010) score were determined from 24 hour food recall collections. Associations were modeled using multinomial logistic and linear regression.

Results—Neither third trimester maternal diet quality nor macronutrient consumption was associated with GWG after adjusting for pre-pregnancy BMI, maternal age, and parity. A ten-point lower HEI-2010 score was associated with 200 g higher infant birth weight and a 1.0 cm longer length. However, maternal HEI-2010 and macronutrient composition were unrelated to infant percent body fat, ponderal index or abdominal circumference.

Conclusion—Poorer third trimester maternal diet quality was associated with higher birth weight and longer length, but was unrelated to markers of infant adiposity. GWG was independent of third trimester maternal diet composition and quality.

Keywords

Birth weight; gestational weight gain; infant adiposity; maternal diet

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The authors report no conflicts of interest.

Presentation: This work was presented at the 63rd Annual Clinical and Scientific Meeting of the American College of Obstetricians and Gynecologists in San Francisco, CA, May 2–6, 2015 as poster #272.

Introduction

Pregnancy is usually associated with significant increases in maternal weight and body composition.[1] Increased fat stores, decreased maternal insulin sensitivity, and other metabolic adaptations allow for essential nutrient delivery to the fetus permitting appropriate growth *in utero*.[2,3] These metabolic shifts lead to increased maternal need for dietary protein and calorie intake.[4–8] Once these basic survival needs are met, however, the characteristics of the maternal diet that would optimize perinatal outcomes are unknown. This deficit in our knowledge prevents the generation of evidence-based guidelines for diet composition and quality during pregnancy.

Weight gain in normal pregnancies allows for fetal growth and development.[3,9] Gestational weight gain (GWG) is commonly thought to serve as an important surrogate of maternal nutrition in pregnancy, and excess GWG has been associated with worse pregnancy outcomes including macrosomia, gestational diabetes, preeclampsia, and cesarean delivery as well as postpartum weight retention.[10–12] Women are routinely counseled throughout pregnancy on recommendations for GWG based on their pre-pregnancy BMI, in accordance with Institute of Medicine guidelines.[13] Several observational studies have suggested that, in addition to parity, smoking history, pre-pregnancy body mass index (BMI, kg/m^2) and sociodemographic characteristics, diet and physical activity play a role in GWG.[14–20] Nevertheless, solid studies of diet composition and related fetal outcomes remain sparse and conflicting.[21] A better understanding of the role that diet quality and composition play in determining GWG and its sequelae could lead to new modifiable risk factors appropriate for targeted interventions.

Furthermore, growing evidence suggests that the prenatal period is a critical window for the development of chronic diseases in the next generation.[22,23] For example, increased birth weight, length, abdominal circumference, ponderal index (PI) and infant adiposity at the time of birth are important indicators of risk for obesity, cardiovascular disease, and diabetes later in life.[11,24–30] The risk of heart disease, diabetes and obesity are also seen in large for gestational age (LGA), or macrosomic infants and infants born to mothers with excessive GWG.[24–26,31–35] Despite the importance of these associations, few studies have sought to describe the association, if any, between maternal diet quality and composition in pregnancy and infant birth weight and adiposity.

Therefore, we hypothesized that healthy indicators of maternal diet composition and quality would suppress GWG and infant body composition including birth weight, PI, and infant adiposity at the time of delivery.

Materials and Methods

This was a secondary data analysis of a prospective, observational pilot study on the effect of third trimester maternal body composition and diet in pregnancy on placental function and fetal growth, as described previously.[36] Forty-one healthy pregnant women with a singleton gestation of varying pre-pregnancy BMI (n=11 normal weight, BMI 18.5 – 24.9 kg/m^2; n=15 overweight, BMI 25 – 29.9 kg/m^2; and n=15 obese, BMI $\geq$ 30 kg/m^2) were recruited from Oregon Health & Science University (OHSU) Obstetric clinics from July 2012 to August 2013. Exclusion criteria included active maternal infection, documented fetal congenital anomalies, substance abuse, chronic illness requiring regular medication use, maternal diabetes, significant medical conditions (active cancers, cardiac, renal, hepatic, or pulmonary disease), or any abnormal values on the 2 hour 75-g glucose tolerance test. The OHSU institutional review board approved the study protocol and each subject provided signed informed consent prior to enrollment.

All women received standard obstetric care per recommendations by the American College of Obstetricians and Gynecologists and the Institute of Medicine (IOM).[37, 38] Subjects presented for their study visit at 37–38 weeks gestation in the morning following an overnight fast. They completed the 24-hour food recall and underwent body composition assessment via air displacement plethysmography using the BodPod (Life Measurement, Inc. Concord, CA). 24-hour food recalls, a well-validated tool for assessing diet, were used to determine both macronutrient intake and diet quality, as measured by 2010 Healthy Eating Index (HEI-2010).[40, 41] Subjects were called on random days by trained study staff in the subsequent 2–3 week period after their study visit to collect two additional 24-hour food recalls to include a total of two weekday and one weekend day. These three 24-hour food recalls were averaged to calculate macronutrient consumption and a HEI-2010 score, in accordance with established strategies used in the nutrition literature.[42,43] Per USDA recommendations, HEI-2010 score of < 51 was considered "poor," 51–80 "needs improvement" and >80 "good."[44] Weight prior to pregnancy was subtracted from weight at the final prenatal visit within one week of delivery to determine GWG. Estimated fetal weight was not assessed prior to enrollment. Neonatal measurements were taken within twenty-four hours of delivery. Skin fold thickness measurements (SFTM) were collected by trained study staff, in accordance with previously documented and widely accepted procedures as well as additional measurements including weight, abdominal circumference, and length.[45] Neonatal fat mass was calculated using the equation developed by Catalano, et al. and converted to percent body fat, which was used as the standard for infant adiposity throughout this study.[45, 46] These measurements were also used to calculate PI (birth weight(g)×100/[length(cm)]^3) using established equations.[47] Confounders were selected based on *a priori* subject matter knowledge and included maternal age (continuous) and parity (nulliparous, multiparous).[48]

Statistical Analysis

We assessed unadjusted associations between exposures and outcomes using Pearson's correlation coefficients and analysis of variance (ANOVA). Linear and multinomial logistic regression analyses were used to estimate the effect of diet composition and quality during the third trimester of pregnancy on seven outcomes: GWG, adherence to GWG recommendations, infant adiposity as determined by percent body fat, birth weight, length, abdominal circumference, and PI.

Exposures included maternal macronutrient intake (protein, carbohydrate, fat), and HEI-2010 to estimate diet quality. The Multivariate Nutrient Density Model approach, as described by Hu, et al, was used to estimate the effects of maternal macronutrient intake on maternal and neonatal outcomes, controlling for total energy and sociodemographic confounders. All statistical analysis was performed using Stata/MP, version 13.1.[49]

Results

Maternal and infant characteristics are show in Table 1. The mean (+SD) maternal age was 30.9 years (±5.8). Mean caloric intake for all women was 2382 kcal, with an average of 34% percent of calories coming from fat, 51% from carbohydrates, and 15% from protein. The mean and range HEI-2010 was 67 [48–92]. The mean (+SD) GWG for all women was 10.5 kg (±6.7 kg), ranging from a loss of 13.5 kg to a gain of 30.7 kg. Women were relatively evenly divided across the IOM recommended GWG adherence, from inadequate (n=12), to adequate (n=13) and excess (n=16). The mean (+SD) infant birth weight was 3.5 kg (±0.4), with a mean (+SD) neonatal fat mass of 0.43 kg (±0.2).

Mean GWG differed across categories of BMI (p=0.01), with women who were normal weight gaining, on average, 11.3 kg during pregnancy, compared to 13.6 kg for women who were overweight, and 6.8 kg for women who were obese(Table 2). Of note, the GWG result in the obese category was influenced by one woman who lost a significant amount of weight during her pregnancy. Despite this, based on outlier analysis and verification of accuracy of the data collected on this individual, she was kept in the final analysis and the distribution of GWG was found to be normal, as verified by the Shapiro-Wilk test. No other outcomes were significantly related to category of pre-pregnancy BMI. With regard to parity, only infant percent body fat was greater in multiparous than nulliparous mothers.

While consuming fewer percent calories from fat and a greater percent of calories from carbohydrates were associated with greater GWG, these relationships were no longer significant after adjusting for total energy intake, maternal age, parity, and BMI (Table 3). Similarly, maternal diet quality as assessed by HEI-2010 was not significantly associated with GWG, either before or after adjusting for these same confounders.

When women with inadequate or excess GWG were compared to women with adequate GWG, there was no association with BMI, parity, maternal age, total energy intake, or macronutrient diet content, after controlling for the same maternal confounders (Table 4).

Macronutrient composition of diet during the third trimester of pregnancy was not significantly associated with any infant outcomes in crude or adjusted models (data not shown), higher quality maternal diet (higher HEI-2010) scores were significantly associated with both lower birth weight and shorter length. Each 1-point increase in HEI-2010 score was associated with 20 g lower birth weight and 0.1 cm shorter length (Table 5) at the time of delivery. However, there was no association between HEI and infant percent body fat, PI, or abdominal circumference.

Comment

Contrary to our hypothesis, we found no association between maternal third trimester HEI-2010 score or percent consumption of protein, fat and carbohydrates and GWG or the likelihood of inadequate, adequate, or excess GWG per the IOM guidelines. However, higher maternal diet quality, as assessed by the HEI-2010 score, was negatively associated with infant birth weight and length. This finding suggests that as a woman's diet quality decreases, the likelihood of having a larger infant as measured by weight and length at birth is increased. However, there was no association with maternal HEI-2010 score and infant percent body fat or PI. Similarly, there was no association between maternal third trimester percent consumption of protein, fat, or carbohydrates on infant body composition. This is in contrast to the recent study by Crume et al showing that neonatal adiposity was associated with increased maternal fat and carbohydrate intake, although they did not take diet quality into account, and concluded that these data were "suggesting that most forms of increased caloric intake contribute to fetal fat accretion".[51]

While studies have been conducted to assess the relationship between maternal diet composition in pregnancy and GWG, many of these studies have been of poor quality or have found no association between macronutrient intake and GWG, limiting what conclusions can be drawn about this interplay.[17,52,53] A recent meta-analysis conducted in 2016 concluded that there is a dearth of high-quality data addressing the role of macronutrient intake on the likelihood of gaining excess weight during pregnancy and that, among those studies that are of high-quality, there remains a considerable amount of discordance in their findings.[21] While it is plausible that there is an association between diet composition during pregnancy and GWG, it may be that the impact of diet earlier in pregnancy plays a more important role in this relationship and that by measuring diet only in late pregnancy we are not measuring this association. Alternatively, it is possible that the role of various specific types of fats and sugars is greater than originally appreciated, and that our macronutrient measures mask these relationships.

Clinical guidelines and recommendations for nutrient intake during pregnancy assume that maternal weight added during this time is affected by diet, generally focusing on recommending healthy eating and exercise to gain within the recommended amount.[37,53,54] In contrast, our findings suggest that third trimester maternal diet quality is unrelated to GWG. Conversely, poorer diet quality, rather than caloric intake, may be related to higher infant weight and length at birth.

Dietary assessment is inherently challenging to study given its subjective nature. However our use of validated and standardized dietary recalls administered by trained staff likely limited some of the error inherent in the process of collecting such data. Additionally, the use of multiple food recalls, spanning both weekdays and weekends, also improved the strength of the data collected. While it is important to comment on the possibility of individuals adjusting their diet as a result of enrollment in the study, the assessment of dietary data at multiple unscheduled time points was an attempt to limit such an effect. There are very few studies in the current body of literature on this topic that have included such robust dietary measures in a population along with detailed infant and maternal outcomes, lending additional strength to the results of this study. The lack of data regarding activity level and exercise is an additional limitation that may have influenced results.

The modest number of individuals enrolled may also have influenced results. Future studies enrolling more participants with expanded dietary measures looking at the impact of diet earlier in pregnancy on these valuable predictors is warranted.

Conclusions

GWG and infant outcomes, including birth weight, length and infant adiposity are important predictors of long-term health effects in mothers and infants.[55] Unfortunately, the role of maternal diet in influencing these variables remains poorly understood, which limits the ability for clinicians and public health officials to educate pregnant women on appropriate consumption in pregnancy to improve maternal and neonatal outcomes. In our study, third trimester maternal diet quality or macronutrient composition was not associated with GWG. However, maternal diet quality, was associated with infant birth weight and length, suggesting that diet quality, not composition, plays an important role in *in utero* growth and development but not necessarily adiposity at time of delivery. These results address some of the important questions regarding the role of maternal diet during this crucial time period and demonstrate the need for further research of earlier time points in pregnancy. Such data are needed for the development of evidence-based guidelines for pregnant patients and women of child-bearing age.

Acknowledgments

Financial Disclosure statement: This work was funded by KL2RR024141 06 (NEM) and OCTRI NCRR/NCATS-funded CTSA grant UL1TR000128 (NEM).

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Table 1

Characteristics of participating mothers and infants at birth.

Maternal Characteristics[a], N = 41	**Mean (±SD) or N (%)**
Age, y, mean	30.9(5.8)
Maternal age, y	
Non-AMA(<35)	30 (74)
AMA (≥35)	11 (26)
Pre-pregnancy BMI, kg/m^2	29.7 (7.1)
Pre-pregnancy BMI	
Normal (<25)	11 (26)
Overweight (25–30)	15 (37)
Obese (>30)	15 (37)
Parity	
Nulliparous	24 (59)
Multiparous	17 (41)
24-hour food recall	
Total calories (kcal)	2382 (±556)
Percent calories from fat	34 (±7)
Percent calories from carbohydrates	51 (±8)
Percent calories from protein	15 (±3)
HEI-2010	67 (±9.7)
GWG (kg)	10.5 (±6.7)
Institute of Medicine GWG adherence	
Inadequate	13 (32)
Adequate	12 (29)
Excess	16 (39)
Infant Characteristics[a]	
Birth weight (kg)	3.5 (±0.4)
Neonatal Fat (kg)	0.43(±0.2)
Abdominal circumference (cm)	33.5 (±1.8)
Ponderal index (kg/cm^3)	25.8 (±3.0)
Length (cm)	51.5 (±2.4)

[a]All continuous variables assessed and found to be normally distributed

GWG, Gestational weight gain, *AMA*, Advanced Maternal Age.[50]

Table 2

Outcomes across pre-pregnancy BMI category and parity

	GWG (kg) Mean ±SD	Neonatal Fat (%) Mean ±SD	Abd Circ (cm) Mean ±SD	PI(g/cm^3) Mean ±SD	Length (cm) Mean ±SD	Birth Weight (kg) Mean ±SD
Pre-pregnancy BMI						
Normal (n=11)	11.3±2.4[a]	0.10 ±0.02	32.8±2.2	24.4±1.1	52.0±2.4	3.5±0.5
Overweight (n=15)	13.6±6.5	0.12 ±0.03	33.7±1.8	25.9±3.1	51.4±2.4	3.5±0.3
Obese (n=15)	6.8±7.5	0.13 ± 0.04	33.8±1.5	26.7±3.6	51.2±2.6	3.6±0.5
	GWG (kg) Mean ±SD	Neonatal Fat (%) Mean ±SD	Abd Circ (cm) Mean ±SD	PI (g/cm^3) Mean ±SD	Length (cm) Mean ±SD	Birth Weight (kg) Mean ±SD
Parity						
Nulliparous (n=24)	10.6 ±7.8	0.11 ±0.03[b]	33.1±1.9	25.4±2.7	51.2±2.6	3.4±0.4
Multiparous (n=17)	10.3 ±5.0	0.13 +0.03	34.1±1.5	26.4±3.3	51.9±2.1	3.7±0.4

[a] p=0.01 for ANOVA comparing GWG across category of pre-pregnancy BMI;

[b] p<0.05 for ANOVA comparing neonatal fat percentage across level of parity;

GWG, Gestational Weight Gain; *AC*, abdominal circumference; *PI*, ponderal index.

Table 3

Linear regression model for maternal GWG and diet in third trimester

	GWG, kg (95% CI)	
	Crude model	**Adjusted model**
Calories Model		
Calories from fat	***−0.34 (−0.64, −0.05)***	−0.02 (−0.69, 0.67)
Calories from carbohydrates	***0.32 (0.07, 0.57)***	0.35 (−0.24, 0.94)
HEI-2010 Model		
HEI-2010	0.04(−0.18, 0.26)	−0.02(−0.24, 0.19)

Model adjusted for pre-pregnancy BMI, maternal age, total energy intake, and parity; Statistically significant results ($p<0.05$) are bold and italicized;

GWG, Gestational weight gain; *HEI*, Healthy-eating index-2010

Table 4

Summary of logistic regression model for IOM gestational weight gain categories

Gestational Weight Gain (categorical)	Inadequate vs. Adequate OR (95% CI)	Excess vs. Adequate OR (95% CI)
BMI	1.1 (0.9, 1.2)	1.1 (1.0, 1.3)
Parity	1.3 (0.2, 9.8)	1.3 (0.2, 8.4)
Maternal age	1.0 (0.8, 1.1)	1.0 (0.9, 1.2)
Total energy	0.6 (0.2, 1.6)	1.0 (0.4, 2.4)
Calories from fat	0.8 (0.5, 1.1)	0.8 (0.6, 1.2)
Calories from carbohydrates	0.8 (0.5, 1.1)	0.9 (0.7, 1.2)

Model adjusted for pre-pregnancy BMI, maternal age, total energy intake, and parity

OR, Odds ratio; *CI*, Confidence interval

Table 5

Association of neonatal outcomes with each one point change in HEI-2010

	Infant Adiposity, % (95% CI)		Birth weight, g (95% CI)		Length, cm (95% CI)		PI, g/cm^3 (95% CI)		AC, cm (95% CI)	
	Crude	**Adjusted**	**Crude**	**Adjusted**	**Crude**	**Adjusted**	**Crude**	**Adjusted**	**Crude**	**Adjusted**
HEI	<−0.01(<−0.01, 0.01)	<−0.01 (<−0.01, 0.01)	***−20.0 (−30.0, −10.0)***	***−20.0 (−30.0, −10.0)***	***−0.08 (−0.16, −0.01)***	***−0.10 (−0.18, −0.01)***	<0.01 (−0.1, 0.1)	<−0.01 (<−0.01, 0.01)	−0.05 (−0.1, 0.1)	−0.04 (−0.1, 0.03)

Model adjusted for pre-pregnancy BMI, maternal age, total energy intake, and parity

HEI, Healthy Eating Index; *CI*, confidence interval; *PI*, ponderal index, *AC*, abdominal circumference